Financial Contagion between United States and European Markets

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Abstract

This paper investigates the existence of financial contagion between the US stock market and 10 European stock markets. Using intraday data for a large set of 374 equities for the period January to June 2011 of three different sectors we investigate the impact of the consumer confidence index announcements in both the US market and related European markets. We apply Garman and Klass (1980) volatility estimator to calculate asset volatility which differs from the classical volatility estimator which cannot reflect fluctuations within a period. Our results indicate that spillover of asset prices volatility from the US to European markets does exist; the greatest impact in the volatility in the target markets is observed in the first minute after the increase in asset prices volatility in the US market and the level of markets interconnection is different among sectors.

Keywords: Financial Contagion, Consumer Confidence Index, European Stock markets

Introduction

In August 2011, Wall Street experienced one of the most volatile weeks in history. The wild volatility spread over quickly across Europe and Asia due to the high level of linkages and interactions between each single market in the world. Financial contagion is not a new phenomenon but its popularity has been growing with time. As time passes, it becomes a more crucial theme in the era of information technology because markets are more interdependent with more information spreading between markets more quickly. Previous studies tend to address this topic by using daily data which does not account properly with how quickly interconnected trading venues spread information is reflected in increased volatility.

The aim of this paper is to analyze the financial contagion between the US market and ten European markets (Athens, Brussels, Paris, Frankfurt, London, Madrid, Dublin, Milan, Stockholm and Zurich) from January to June 2011. We use intraday equity data for three different industries (*Financials*, *Healthcare* and *Industrials*) for a total of 374 equities. This study will analyze whether there is a sign of transmission of volatility from US market to the European markets during the examined period. We apply Garman and Klass (1980) volatility estimator to calculate asset volatility which differs from the classical volatility estimator which cannot reflect fluctuations within a period. Garman-Klass estimator is well known for coping with high frequency or intraday data using the open, close, high and low prices within a time period for the calculation of volatility, which can create a better picture for fluctuations in high-frequency data. The US consumer confidence index released monthly is the reference time point in our analysis.

This study contributes to the existing knowledge in financial contagion at different levels. First, as the technology level is so advanced that new incoming information into the market can be quickly realized by market participants, we use minute per minute data in order to catch up with the information processing efficiency. Second, previous studies tend to use global market indices to represent the whole market movements. In this study self-built industry indices are used which allows to implement the same index methodology across different markets and therefore a more accurate test of the consumer confident index announcement effect across industries and a more convincing investigation of financial contagion between industries in different markets. Finally, we address the issue of denominated currency for each target market and its influence in financial contagion.

The results can be summarized as follows. Firstly, we find evidence that spillover of asset prices volatility from the US to European markets does exist in the examined period from January

2011 to June 2011. Secondly, the greatest impact in the volatility in the target markets is observed in the next minute after the increase in asset prices volatility in the US market and it is highest in the first 5 minutes over a period of 30 minutes analyzed. Thirdly, the level of markets interconnection is different among industries. Finally, denominated currency is an important factor that affects the spillover effect of volatility from the US market to the target markets.

The remainder of the paper proceeds as follows. The next section provides a brief literature review in financial contagion, the third section describes the data sample and models specification, and section 4 presents the empirical results. Section 5 concludes the study.

Literature review

Financial contagion is not a new research topic but its popularity has been growing with time. As time passes, financial contagion becomes a more crucial theme in the era of information technology because markets are more interdependent with more information spreading between markets more quickly. In the early 90s, King and Wadhwani (1990) using high frequency data studied how volatility is transmitted between London, New York and Tokyo stock markets analyzing contagion between markets with overlap and non-overlap trading hours. They find significant increase in correlation coefficient after the stock market crush in October 1987.

In recent years several studies were undertaken on financial contagion being one of the debatable issues the definition of financial contagion (Pericoli and Sbracia, 2003). The most commonly defines contagion as a significant increase in cross-market links conditional on a crisis occurring in one market (Coresetti et al 2010, Caporale et al 2005, Yiu et al 2010, Forbes and Rigobon 2001, Chiang et al 2007, Pritsker 2000, among others). Forbers and Rigobon (2002) also distinguished the concept of “contagion” versus “independence”, where contagion is a sudden increase in correlation between markets where interdependence accounts for situation of continuously high level of correlation. They looked into three time periods, 1987 US market crash, 1994 Mexican devaluation and 1997 Asian crisis by using two days rolling average of returns of related market indices and found that there was no contagion but only high level of market co-movements in the three periods, which they suggested as markets interdependence. Later, Caporale *et al* (2005) focused in eight countries from East Asian region during the 1997 Asian financial crisis, defining financial contagion as a significant increase in the degree of co-movements between stock returns in different countries. Caporale *et al* (2005) used parameter stability test in the hypothesis testing and GARCH (1,1) model to overcome the bias of heteroskedasticity, endogeneity and omitted variables. They find that there was contagion effect within East Asian region during the 1997 Asian financial crisis.

The diverse transmission channels through which financial contagion between cross-border markets can be spread are divided in the correlated information channel (King and Wadhwani, 1990), liquidity channel (Claessens *et al*, 2001), cross-market hedging channel (Kodres and Pritsker, 2002) and wealth effect channel (Kyle and Xiong, 2001). Additionally different measures and models were used in the financial contagion analysis such as cross market correlation coefficient (King and Wadhwani 1990, Lee and Kim 1993, Calvo and Reinhart 1996), ARCH or GARCH framework (Hamao, Mausulis and Ng 1990, Edwards 1998), cointegration techniques (Longin and Solnik 1995, Chou, Ng and Pi 1994, Cashin, Kumar and McDermott 1995) and international transmission mechanisms (Eichengreen, Rose and Wyplosz 1996, Forbes 2000). More recently Diebold and Yilmaz (2009) proposed the spillover index methodology for investigating financial contagion which is based on the vector autoregressive model and can be applied on both asset returns and volatility.[1] None of the previous studies on financial contagion used high-frequency data. Yiu *et al* (2010), Diebold and Yilmaz (2009), Suwanpong (2011), Coresetti et al (2010) and Caporale et al (2005) use data on weekly basis. Forbes and Rigodon (2002) and Coresetti et al (2005) use a shorter time interval of 2 days returns in calculating correlations. The shortest interval set among the literature use daily basis returns in the analysis (Chiang et al, 2007).

Gathered from prior work on financial contagion most research has been conducted by the use of market indices to represent the whole market movement. However, it is well-known that world major indices are positively correlated with each other, therefore would be worth studying if a particular industry would move closer with the US market than other industries. This analysis could bring additional insights in the debate among contagion and markets independence.

Data and methodology

Data Sources and Collection Procedures

In this study we use the US market as the originating market and ten European markets as target markets which are the United Kingdom, France, Ireland, Greece, Sweden, Germany, Belgium, Switzerland, Spain and Italy. As different industries may have different level of contagion from the originating market to the others, looking at only the market overall index would be too general. Therefore, we collect intraday minute per minute data (open, close, high and low stock prices) from

[1] Yilmaz (2010) and Suwanpong (2011) also used the spillover effect in their work.

stocks listed in the three industries analyzed (*Financials*, *Healthcare* and *Industrials*) generating indices for each of them using a price weighted approach. All data were collected from Bloomberg Terminal by Bloomberg L.P. The most common stock indices were used for industry stock collection, the Athens Composite Index (ACI), BEL 20 Index (BEL 20), CAC 40 Index (CAC 40), DAX 30 Index (DAX 30), FTSE 100 Index (FTSE 100), FTSE MIB Index (FTSE MIB), IBEX 35 Index (IBEX 35), ISEQ 20 Index (ISEQ 20), OMX Stockholm 30 (OMXS 30), SMI Index (SMI) and S&P 500 Index (S&P 500) for New York market. The details of the indices and the industry classification standard are listed below.

Table 1: Indices used and their classification standards

Markets	Indices	Classification Standards[2]
New York	S&P 500	GICS
Athens	Athens Composite Index	ICB
Brussels	BEL 20	ICB
Paris	CAC 40	ICB
Frankfurt	DAX 30	Prime Standard
London	FTSE 100	ICB
Milan	FTSE MIB	ICB
Madrid	IBEX 35	IGBM
Dublin	ISEQ 20	N/A
Stockholm	OMXS 30	GICS
Zurich	SMI	ICB

As listed in the above table, the classification standards adopted by the 11 indices are not the same. To universalize the classification standards in this paper, ICB was chosen since more than half of the indices follow this standard. The three common industries indices were re-classified with a total of 374 stocks selected as in the table 2 below:

[2] GICS stands for Global Industry Classification Standard, ICB for Industrial Classification Benchmark and IGBM for Madrid Stock Exchange General Index

Table 2: Number of stocks by market and industry

Index	Financials	Healthcare	Industrials	Total
S&P 500	82	51	62	195
Athens Composite Index	9	1	9	19
BEL 20	6	2	2	10
CAC 40	6	2	8	16
DAX 30	5	4	5	14
FTSE 100	24	4	13	41
FTSE MIB	12	1	7	20
IBEX 35	8	1	10	19
ISEQ 20	3	2	3	8
OMXS 30	5	2	11	18
SMI	5	5	4	14
TOTAL	165	75	134	374

As per table 2 above, for all markets except Madrid, Paris and Stockholm, the *financials* sector is the one with larger number of stocks in the sample and in three of the markets its value is above 55 percent. This is a good indication that analyses of financial contagion settled in major indices are bias towards some sectors. Additionally, this bias is not homogeneous since some markets are more oriented to one sector then others. In fact *Industrials* sector is relatively more important in Madrid, Paris and Stockholm and *healthcare* sector is relatively more important in Frankfurt, New York and Zurich. Additionally we had to consider the open and close times in different markets. In fact, some macroeconomic indicators cannot be considered due that the US and European markets are not both open by the time the announcement is made. For example, unemployment rate in the US is announced when European markets are open while the US market it is closed. In this case European markets reaction will be prior to the US market which goes beyond the objective of analyzing how the volatility increase in the US market spillover to the European markets. Another example is for the Federal Fund rate, it is announced when European markets are closed but when the US market is still opened. Though the US market reacts to the announcement prior to the European markets, volatility in European markets on the next day when they are opened cannot be judged to be influenced by the volatility in US market. The Consumer Confidence Index was selected among a pool of economic indicators as the triggered event due that all markets analyzed are open when the index is released (10.00 am EST). This index reflects the households' confidence towards the country's economy. Therefore, this confidence indicator affects broadly all sectors of the economy and provides vital information to the financial markets due consumer spending accounts for two-thirds of the US economy. During the six months period analyzed the index was announced on January 25, February 22, March 29, April 26, May 31 and June 28.

Table 3 and figure 1 shows the market open and close times, as well as the announcement time for each market in both local and London time. The timeline shows a graphical representation on opening hours of the markets in London time.

Figure 1: Trading hours and consumer confidence index announcement time under London time

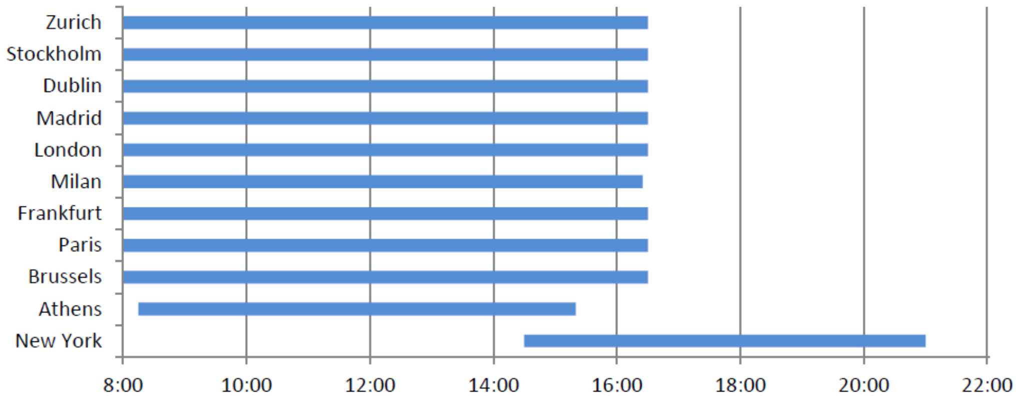


Table 3: Trading hours and consumer confidence index announcement time under Local and London time

	Local Time			London Time		
Market	Opening Time	Closing Time	Announcement Time	Opening Time	Closing Time	Announcement Time
New York	09:30	16:00	10:00	14:30	21:00	15:00
Athens	10:00	17:20	17:00	08:00	15:20	15:00
Brussels	09:00	17:30	16:00	08:00	16:30	15:00
Paris	09:00	17:30	16:00	08:00	16:30	15:00
Frankfurt	09:00	17:30	16:00	08:00	16:30	15:00
Milan	09:00	17:25	16:00	08:00	16:25	15:00
London	08:00	16:30	15:00	08:00	16:30	15:00
Madrid	09:00	17:30	16:00	08:00	16:30	15:00
Dublin	08:00	16:30	15:00	08:00	16:30	15:00
Stockholm	09:00	17:30	16:00	08:00	16:30	15:00
Zurich	09:00	17:30	16:00	08:00	16:30	15:00

As shown in the timeline and in table 3, most European markets open and close at the same time as London, except Athens and Milan. For all markets (except Athens) it is possible to analyze intraday data from ten minutes before the announcement to thirty minutes after the announcement.

Volatility estimation

We consider in this study the occurrence of contagion when volatility of asset prices spills over from the "crisis" country to other countries". We use Garman and Klass (1980) volatility estimator to calculate asset volatility which differs from the classical volatility estimator that cannot reflect fluctuations within a period. Garman-Klass estimator is well known for coping with high frequency or intraday data using the open, close, high and low prices within a time period for the calculation of volatility, which can create a better picture for fluctuations in high-frequency data. Also, Garman-Klass estimator was proved to have a much higher efficiency than the classical estimator (Meilijson, 2008; Ślepaczuk and Zakrzewski, 2009). Garman and Klass (1980) suggested two approaches in calculating the volatility of an asset from its prices within a certain period. Following previous work (Meilijson, 2008; Batten and Lucey, 2007; Yilmaz, 2010; Suwanpong, 2011; Diebold and Yilmaz, 2009) we use the "best analytic scale-invariant" approach to preserve the completeness of the estimator. The Garman and Klass (1980) estimator (GKe) is calculated as follows:

$$GKe = \sigma^2 = 0.511(h-l)^2 - 0.019[c(h+l) - 2hl] - 0.383c^2$$

where, h represents the interval high-open, l the interval low-open and c the interval close-open. The volatilities of each minute within the examined time period for each stock were calculated using the above Garman-Klass "best analytic scale-invariant" estimator. The calculated volatilities were then annualized and each stock for the same market and sector were combined to form the annualized volatility of that minute for each market and industry.[3]

Volatility Spillover effect in European Equity markets

Several regression analyses are used to investigate the lead-lag behavior and the financial contagion among different sectors of the ten European markets. As the markets will react to the incoming news, the indices would fluctuate more for a period around the announcement time, showing the investor's reaction to the new incoming information (Ederington and Lee 1993 and Bollerslev *et al* 2000). We extract thirty minutes of data after the announcement time and undertake additional

[3] We assume in our calculations 252 trading days and different trading minutes per day for each market according to table 3. The industry index volatility is calculated with weights and correlations calculated by using the price ratio of the 30th minute before each announcement and 30 minutes of data before the announcement time. As there are thirty three self-made indices and six announcement dates, a self-written VBA programme was created to deal with the massive data.

empirical tests for the first five minutes, due the first five minutes should show greatest volatility compared with other intervals.

Our baseline model tests whether US market volatility of a minute would affect volatility in the next minute in other markets. The regression equation can be defined as follow:

$$GKe_{m,i,t+1} = \alpha + \beta_1\ GKe\_US_{m,t} + \sum_{k=1}^{L} \beta_{2,L} D_{m,i,t} +\ \varepsilon_{m,i,t}$$

Where GKe is the stacked vector of the dependent variable, representing the volatility[4] starting one minute after the consumer confidence index announcement for each mth European market and i^{th} industry index on the t^{th} minute, GKe_US is a vector with the volatility for each i^{th} US industry index starting in the minute of the consumer confidence index announcement and D is a matrix of dummy variables that controls for large increases of volatility observed in the US market indexes in the first five minutes, sectors, markets and denominated market currency. We will run a set of regressions with different specifications to address the objectives of this paper.

Figures 2 to 4 below presents the minute per minute annualized volatility aggregated for the six consumer confidence index announcements between ten minutes before and thirty minutes after the announcement time.[5] They show that there is a surge followed by a plunge in volatility for US followed by European markets aggregated and most of them happened in the first five minutes, which leads to undertake additional empirical tests for the first five minutes of trading after the announcement. Additionally, the US market is less volatile than the aggregation of the ten European markets in particular for the *financials* and *healthcare* sectors. [6]

[4] Note that "volatility" calculated by the Garman-Klass estimator represents the variance but not the standard deviation of an asset price.
[5] Figures reporting each announcement and each European market individually are available upon request.
[6] Further analysis will show that there is not the case when the European markets are analysed individually.

Figure 2: *Financials* sector volatility per minute

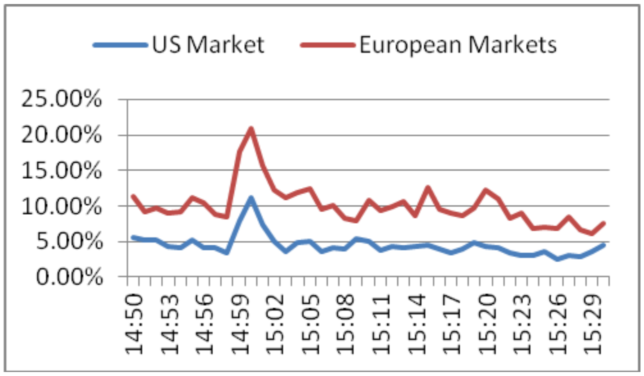


Figure 3: *Healthcare* sector volatility per minute

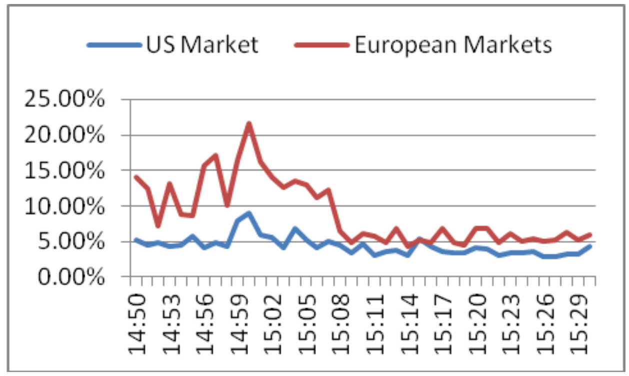
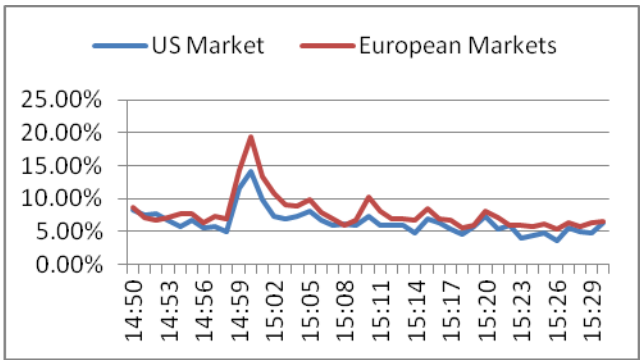


Figure4: *Industrials* sector volatility per minute



Empirical Results

Volatility Spillover effect in European Equity markets

The previous model is estimated to analyze the effect of the US consumer confidence index announcements in the US stock market volatility and its contagion to the European Stock markets. We first test whether US market volatility of a minute would affect the next minute volatility in the European markets. Additionally binary variables are included to evaluate if a substantial increase in the US stock market volatility in the first 5 minutes after the announcement will magnify the financial contagion to the European markets. This substantial increase is quantified in above 30, 40, 50 and 60 percent. We also control our results by industry (*healthcare* and *industrials* being *Financials* the basis case) with the objective to explore whether different industries are more interconnected than others. Table 4 panels A and B, presents per industry the number and percentage of observations of substantial increase in the US market volatility for the next five minutes.

Table 4: US market volatility increase per industry

Panel A: Number of observations

	Sectors		
Percentage increase	*Financials*	*Healthcare*	*Industrials*
Below 30 percent	0	290	870
30 percent	870	0	0
40 percent	0	290	0
50 percent	290	580	0
60 percent	580	580	870

Panel B: Percentage of observations

	Sectors		
Percentage increase	*Financials*	*Healthcare*	*Industrials*
Below 30 percent	0.00%	16.67%	50.00%
30 percent	50.00%	0.00%	0.00%
40 percent	0.00%	16.67%	0.00%
50 percent	16.67%	33.33%	0.00%
60 percent	33.33%	33.33%	50.00%

For all of the financial sector observations there is at least a 30 percent increase in volatility following the announcement. Industrials sector on the one hand is the less volatile of the three sectors with 50 percent of the observations with a volatility increase less than 30 percent but on the other hand accounts for the largest percentage with above 60 percent volatility increase in the first five minutes. That could indicate that the volatility in the financial sector increases independently of the announcement (good or bad news regarding forecasts/expectations) and for the industrials sector the reaction is more linked with the quality of the information and confirmation or not of expectations.

Table 5: Average Volatility in European markets in the first five minutes

	Time in minutes				
Average Volatility	1st minute	2nd minute	3rd minute	4th minute	5th minute
Financials	20.88%	15.67%	12.16%	11.23%	8.88%
Healthcare	20.90%	14.51%	13.00%	11.81%	12.46%
Industrials	19.39%	13.27%	10.75%	9.16%	8.88%

On the side of the European markets the average volatility per sector and per minute varies as well. Table 5 reports the average volatility across the ten European markets analyzed per industry. A clear tendency of volatility decrease over the first five minutes to all the three sectors is observed. *Industrials* are the less volatility sector and *Financials* shows highest combined volatility in the first two minutes with healthcare having that pattern in the remaining three minutes. The results for the

European markets across the sectors are aligned with the announcements effect on volatility for the different sectors in the US. Indeed, this confirms that an analysis of financial contagion across sectors is desirable instead of the use of global market indices.

Table 6 summarizes the results of the baseline model, where six different regressions are presented for different specifications for the independent variables.

Table 6: Volatility Spillover effect in European Equity markets (1)

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
S&P volatility	0.536***	0.669***	0.668***	0.659***	0.644***	0.5846***
	(7.120)	(8.480)	(8.470)	(8.350)	(8.140)	(7.330)
Healthcare		-0.026***	-0.025***	-0.031***	-0.029***	-0.0259***
		(-4.790)	(-4.430)	(-5.460)	(-5.260)	(-4.790)
Industrials		-0.039***	-0.034***	-0.038***	-0.038***	-0.042***
		(-6.810)	(-5.270)	(-6.780)	(-6.730)	(-7.380)
30 percent			0.009			
			(1.470)			
40 percent				0.015***		
				(3.070)		
50 percent					0.017***	
					(3.780)	
60 percent						0.030***
						(6.330)
Constant	0.059***	0.074***	0.0648***	0.067***	0.066***	0.0678***
	(13.100)	(14.800)	(8.020)	(11.720)	(11.870)	(12.770)
Observations	5,220	5,220	5,220	5,220	5,220	5,220
Adj. R-Squared	0.009	0.018	0.019	0.020	0.021	0.026

***, **, * and denotes significance at the 1%, 5%, and 10% level, respectively

On average, one percent increase in the US market volatility has a substantial effect in the next minute volatility in the European markets between 0.536 and 0.669 percent (statistical significant at one percent level). Moreover, if during the first five minutes the volatility in the US market jumps more than 40 percent, there is a marginal increment in the financial contagion among the US and European markets. Finally, *healthcare* and *industrials* sectors are less correlated than financial sectors. These preliminary results shows evidence that spillover of asset prices volatility from the US to European markets does exist and it is amplitude is different from sector to sector.

In table 7 it is analyzed the impact of volatility change for the US market in each minute after the announcement (for a period of 30 minutes) in one to five minutes later in the European markets.

Table 7: Volatility Spillover effect in European Equity markets (2)

Variables	European $markets_{t+1}$	European $markets_{t+2}$	European $markets_{t+3}$	European $markets_{t+4}$	European $markets_{t+5}$
$S\&P_t$	0.669***	0.375***	0.283***	0.268***	0.392***
	(8.480)	(4.950)	(3.870)	(3.800)	(5.830)
Healthcare	-0.026***	-0.027***	-0.027***	-0.028***	-0.030***
	(-4.790)	(-5.050)	(-5.260)	(-5.670)	(-6.180)
Industrials	-0.039***	-0.033***	-0.031***	-0.031***	-0.034***
	(-6.810)	(-6.030)	(-5.840)	(-6.040)	(-6.850)
Constant	0.074***	0.083***	0.085***	0.085***	0.078***
	(14.080)	(16.380)	(17.150)	(17.460)	(16.760)
Observations	5,220	5,040	4,860	4,680	4,500
Adj. R-Squared	0.018	0.011	0.010	0.010	0.017

***, **, * and denotes significance at the 1%, 5%, and 10% level, respectively

We can highlight the average drop in the marginal effect in the European markets as the time lag moves from one to five minutes. All results are statistically significant at one percent level and the positive value for the constant reflects the average higher volatility levels for the sample of European markets compared with US. Again, *healthcare* and *industrials* sectors are less interconnected across markets than *financials* sector. Therefore, the greatest impact in the volatility in the target markets is observed in the next minute after the increase in asset prices volatility in the US market. (See Table 8 p.17)

Even though there is clear evidence in a 30 minutes interval after the announcement of a one minute spillover of asset price volatility between US and European markets, we re-test the analysis for the first five minutes period after announcement for the European markets as a whole and per country individually. The results are shown in table 8 (see Table 8 p.17) where it is regressed the volatility in the European markets one minute after the announcement with the volatility in the US market plus four binary variables with the value of one if there is an increase in the observed volatility minute per minute and zero otherwise between the 1st and the 4th minute. For the European markets as a whole the first and third minutes increase in US market volatility as a positive effect on European markets volatility (statistically significant for one percent level). The results for the 2nd minute are inconclusive and the 4th minute has a negative effect. The coefficient for the 1st minute is the largest confirming the importance and significance of the first minute US market reaction after the announcement. From the results we can highlight as well the less importance of a 2nd minute increase in the US market volatility. In fact, the European markets seems to not react to that information but a 3rd minute with increased volatility has an important impact in European markets volatility. Indeed, an increase of volatility in the US market in the 3rd minute as a positive marginal effect of 7.8 percent on the average volatility for the European markets. These results are robust across different markets with positive coefficient across all European markets for the 1st minute and eight out of ten markets the coefficient for the 2nd minute is negative. One should highlight as well the larger positive effect of an increased volatility in the US market in Paris, Frankfurt, London, Madrid and Stockholm, with coefficients of 1.016, 0.849, 0.683, 1.285 and 0.844, respectively, very above from the remaining markets which tend to be smaller and therefore maybe more out of the sight of the investors. (See Table 9 p.18)

In table 9 the sector and the market currency denomination are included in the regression analysis. Besides two binary variables to control the marginal effect of each sector, two additional binary variables are included where currency 1 binary variable it is equal to one if the denominated currency is the Euro and zero otherwise and currency 2 binary variable it is equal to one if the denominated currency is the Swiss Franc, Swedish krona or Irish pound and zero otherwise.

The results show a confirmation of the spillover effect among the US market and European markets at an aggregate level and per country. In seven of the ten individual regressions per European market the coefficient is positive and statistical significant at one percent level. Additionally, we can observe the importance of the currency denomination in each market. In fact, a market denominated in Euro the effect of increased in volatility in the US market is amplified with an average marginal increase in the volatility of 7.9 percent due to the fact that the market is denominated in Euro in opposition to British pound. No particular differences are found among the denominations in Swiss Francs, Swedish krona or Irish pounds and there is supporting evidence that denominated currency is an important factor that affects the spillover effect of volatility from the US market to the target markets analyzed in this paper.

Conclusions

The aim of this paper was to investigate the existence of financial contagion between the US stock market and 10 European stock markets. Using intraday data for a large set of 374 equities for the period January to June 2011 of three different sectors we investigated the impact of the consumer confidence index announcements in both the US market and related European markets.

The results can be summarized as follows. Firstly, we find evidence that spillover of asset prices volatility from the US to European markets does exist in the examined period from January 2011 to June 2011. Secondly, the greatest impact in the volatility in the target markets is observed in the next minute after the increase in asset prices volatility in the US market and it is highest in the first 5 minutes over a period of 30 minutes analyzed. Thirdly, the level of markets interconnection is different among industries. Finally, denominated currency is an important factor that affects the spillover effect of volatility from the US market to the target markets.

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Table 8: Volatility Spillover effect in European Equity markets (3)

Variables	European Markets	Athens	Brussels	Paris	Frankfurt	London	Madrid	Dublin	Milan	Stockholm	Zurich
S&P	0.528**	-0.516	0.380	1.016***	0.849***	0.683***	1.285***	-0.167	0.471	0.844***	0.438*
	(2.290)	(-0.310)	(1.220)	(3.400)	(2.840)	(3.70)	(3.930)	(-0.540)	(1.020)	(3.760)	(1.660)
1st minute	0.120***	0.950***	0.054	-0.026	0.068*	0.005	0.011	0.059	0.011	0.017	0.056*
	(4.170)	(4.550)	(1.380)	(-0.700)	(1.810)	(0.200)	(0.280)	(1.520)	(0.190)	(0.600)	(1.700)
2nd minute	-0.035	-0.240	0.072**	-0.031	0.009	-0.045**	-0.049	0.093***	-0.077	-0.023	-0.036
	(-1.460)	(-1.400)	(2.260)	(-1.020)	(-0.300)	(-2.390)	(-1.470)	(2.920)	(-1.630)	(-1.010)	(-1.330)
3rd minute	0.078***	1.068	0.056	-0.086**	-0.017	-0.065***	-0.057	-0.032	-0.039	-0.019	-0.030
	(2.940)	(5.560)	(1.570)	(-2.510)	(-0.480)	(-3.040)	(-1.510)	(-0.890)	(-0.740)	(-0.720)	(-0.990)
4th minute	-0.051**	-0.220	0.009	-0.063**	-0.055	-0.028	-0.089***	-0.048*	0.079*	-0.024	-0.071***
	(-2.390)	(-1.420)	(0.300)	(-2.280)	(-1.980)	(0.110)	(-2.940)	(-1.680)	(1.840)	(-1.150)	(-2.900)
Constant	0.005	-0.520	0.000	0.150***	0.047	0.069**	0.084	0.022	0.104	0.038	0.061
	(0.140)	(-1.870)	(0.000)	(3.010)	(0.950)	(2.260)	(1.540)	(0.420)	(1.350)	(1.020)	(1.400)
Observations	900	90	90	90	90	90	90	90	90	90	90
Adj. R-Squared	0.029	0.334	0.024	0.197	0.099	0.309	0.228	0.130	0.112	0.166	0.105

Table 9: Volatility Spillover effect in European Equity markets (4)

Variables	European Markets	European Markets	European Markets	Athens	Brussels	Paris	Frankfurt	London	Madrid	Dublin	Milan	Stockholm	Zurich
S&P	0.650***	0.528**	0.650***	0.521	0.254	1.170***	0.755**	0.695***	1.302***	-0.252	0.814**	0.790***	0.448*
	(2.670)	(2.310)	(2.700)	(0.320)	(0.790)	(3.800)	(2.410)	(3.530)	(3.800)	(-0.760)	(1.800)	(3.320)	(1.640)
1st minute	0.143***	0.0120***	0.143***	1.347***	0.083*	-0.048	0.036	0.003	-0.021	0.052	-0.044	0.004	0.021
	(4.410)	(4.220)	(4.450)	(6.170)	(1.930)	(-1.170)	(0.860)	(0.130)	(-0.460)	(1.190)	(-0.720)	(0.140)	(0.580)
2nd minute	-0.023	-0.035	-0.023	-0.077	0.078**	-0.033	-0.023	-0.045**	-0.059*	0.088***	-0.083**	-0.029	-0.047*
	(-0.950)	(-1.480)	(-0.960)	(09.470)	(2.390)	(-1.070)	(-0.710)	(-2.280)	(-1.710)	(2.650)	(-1.820)	(-1.220)	(-1.710)
3rd minute	0.077***	0.078*	0.077***	1.027***	0.048	-0.079**	-0.014	-0.064	-0.051	-0.033	-0.022	-0.018	-0.024
	(2.900)	(2.970)	(2.930)	(5.740)	(1.370)	(-2.330)	(-0.400)	(-2.970)	(-1.360)	(-0.910)	(-0.430)	(-0.680)	(-0.800)
4th minute	-0.059**	-0.051**	-0.058**	-0.460	-0.029	-0.028	-0.037	-0.025	-0.059*	-0.051	0.161***	-0.018	-0.039
	(-2.370)	(-2.410)	(-2.400)	(-2.770)	(-0.900)	(-0.910)	(-1.150)	(-1.260)	(-1.700)	(-1.520)	(3.500)	(-0.760)	(-1.420)
Healthcare	0.045*	---	0.045*	0.703***	0.038	-0.025	-0.057*	-0.001	-0.051	-0.016	-0.065	-0.024	-0.055*
	(1.700)		(1.720)	(3.970)	(1.090)	(-0.740)	(-1.680)	(-0.050)	(-1.360)	(-0.460)	(-1.320)	(-0.920)	(-1.870)
Industrials	0.009	---	0.009	0.443*	0.086**	-0.080**	-0.033	-0.005	-0.063	0.010	-0.189***	-0.008	-0.066
	(0.35)		(0.350)	(2.420)	(2.380)	(-2.32)	(-0.930)	(-0.240)	(-1.630)	(0.28)	(-3.740)	(-0.320)	(-2.150)
Currency 1	---	0.079**	0.079**	---	---	---	---	---	---	---	---	---	---
		(2.600)	(2.600)										
Currency 2	---	-0.078	-0.008	---	---	---	---	---	---	---	---	---	---
		(-0.240)	(-0.240)										
Constant	-0.041	-0.040	-0.086	-1.248***	-0.040	0.176***	0.107*	0.071**	0.136**	0.038	0.172**	0.063	0.119**
	(-0.860)	(-0.860)	(-1.600)	(-3.950)	(-0.640)	(2.950)	(1.750)	(1.850)	(2.050)	(0.600)	(1.970)	(1.350)	(2.250)
Observations	900	900	900	90	90	90	90	90	90	90	90	90	90
Adj. R-Squared	0.038	0.050	0.052	0.428	0.066	0.233	0.107	0.293	0.236	0.116	0.232	0.155	0.138